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Birch, Heidi; Trac, Ngoc Lam; Mayer, Philipp

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New approaches for determining solubility of volatile liquid chemicals



Heidi Birch*, Lam Ngoc Trac and Philipp Mayer
*hbir@env.dtu.dk

Introduction

Water solubility is a fundamental parameter in environmental risk assessment of chemicals, and is theoretically a simple parameter to determine.

Main challenge for liquid hydrophobic chemicals:

- avoiding formation of dispersions or micro-droplets
- while establishing equilibrium within a reasonable time frame

Two new approaches were directed at solubility determinations:

- 1) Passive dosing from a saturated silicone polymer¹
- 2) Dosing from pure phase liquid through the headspace²

Experimental setup

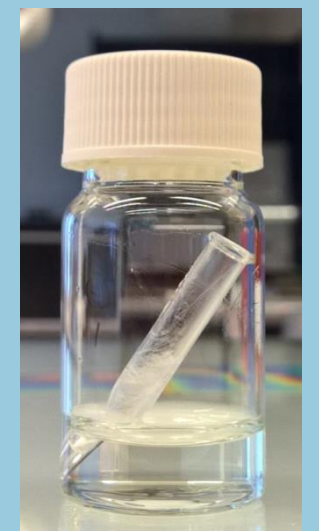
Passive dosing from saturated silicone

- Cleaned silicone rod (diameter: 3mm) was cut into pieces of 0.4 g (See A, bottom panel)
- Rods were loaded by immersion in the liquid test chemical
- Loaded rods were wiped with damp lint free tissue and rinsed three times with water
- Water was added to the loaded rods and equilibrated on a roller at 20 rpm (B & C)



Equilibration through headspace

- Glass wool was placed in glass inserts in 20 mL vials
- Liquid test chemical was added to the inserts
- Water was added to the vials
- Vials were shaken at 200 rpm, 10mm orbit for 23 hours



Test chemicals: dodecylbenzene, isopropyl myristate, hecylcyclohexane, +αPinene (D)
Analysis was done using liquid/liquid extraction with iso-octane (1-5 mL iso-octane to 5-10 mL sample) and GC-MS (E). Calibration by ¹³C labeled standard for Dodecylbenzene and external standards for all other compounds.

Silicone loading kinetics

- Loading kinetics were determined for dodecylbenzene
- 30 rods were placed in dodecylbenzene and rolled at 20 rpm.
- At certain time steps, five rods were removed and wiped
- Swelling was determined by weight

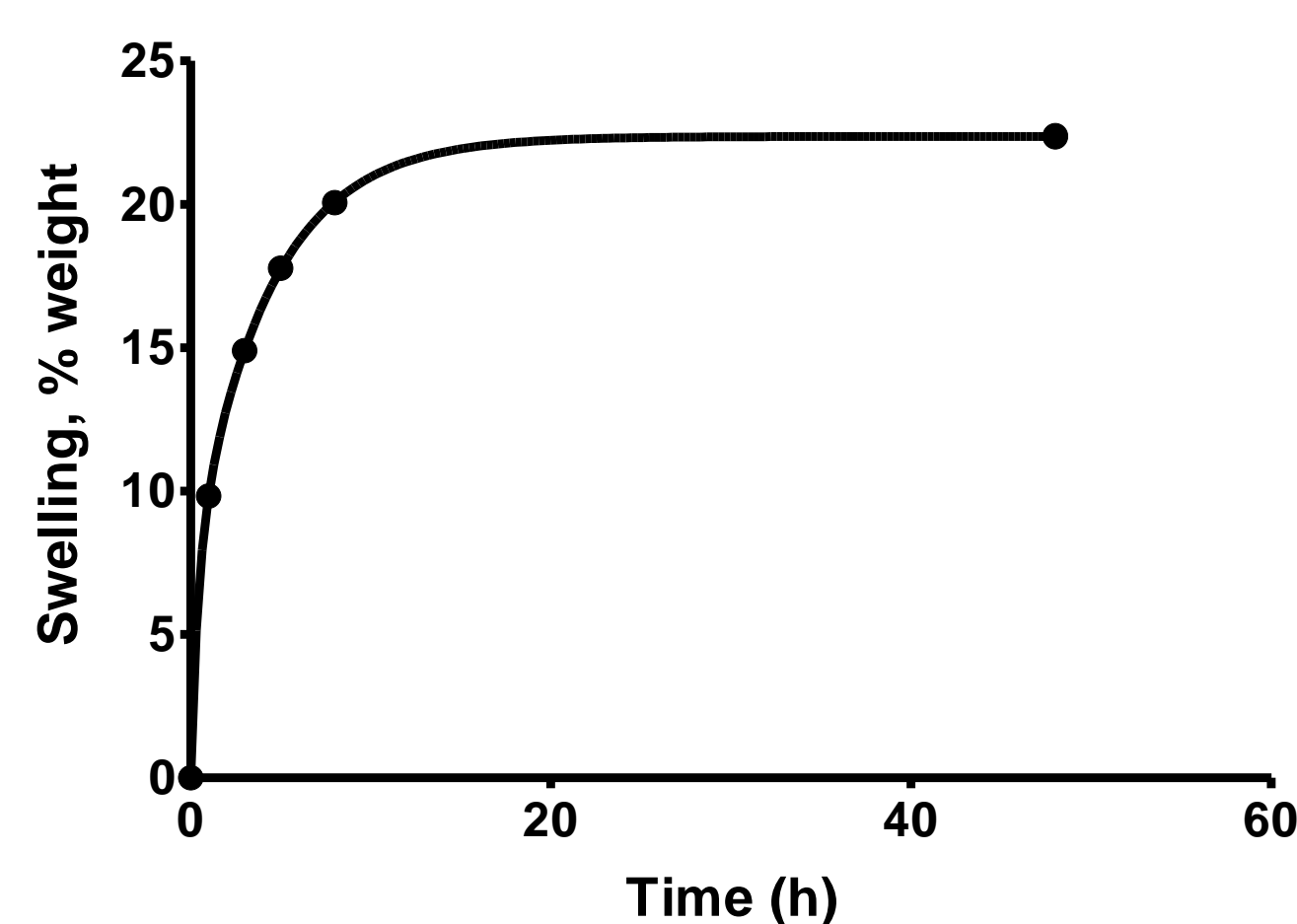


Figure 1: Swelling kinetics for 3 mm silicone rod immersed in dodecylbenzene.
Fit: First order biphasic model

Swelling times:

$t_{95\%}$ of max swelling = 11 hours

$t_{99\%}$ of max swelling = 18 hours

Cross-validation

Measured solubility

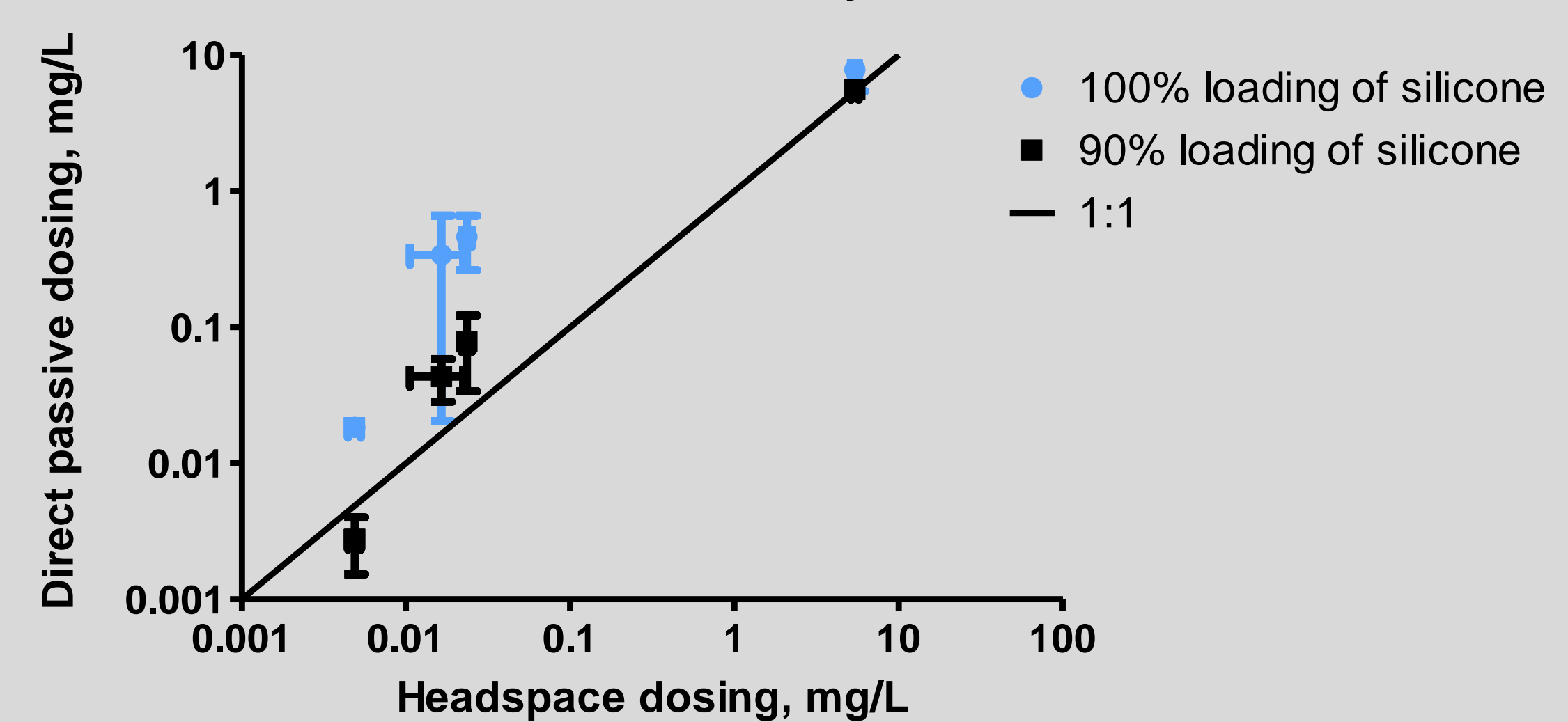


Figure 4: Solubility measured by direct passive dosing from 100 and 90% swelling of silicone as a function of solubility measured by headspace dosing. Mean and s.d., n=3

Generating saturated solutions

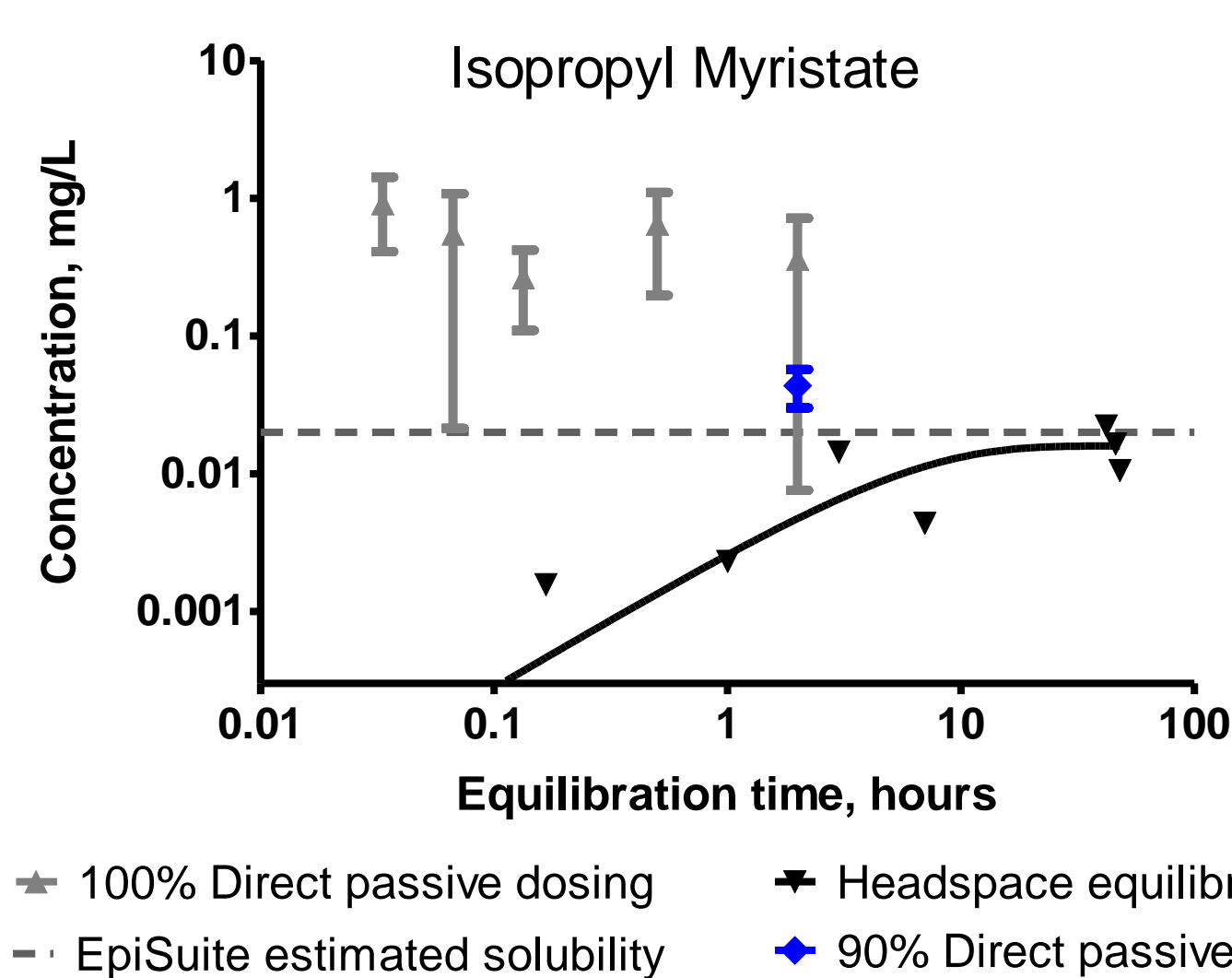


Figure 2: Equilibrium kinetics for direct passive dosing and headspace dosing of isopropyl myristate. Mean and s.d.

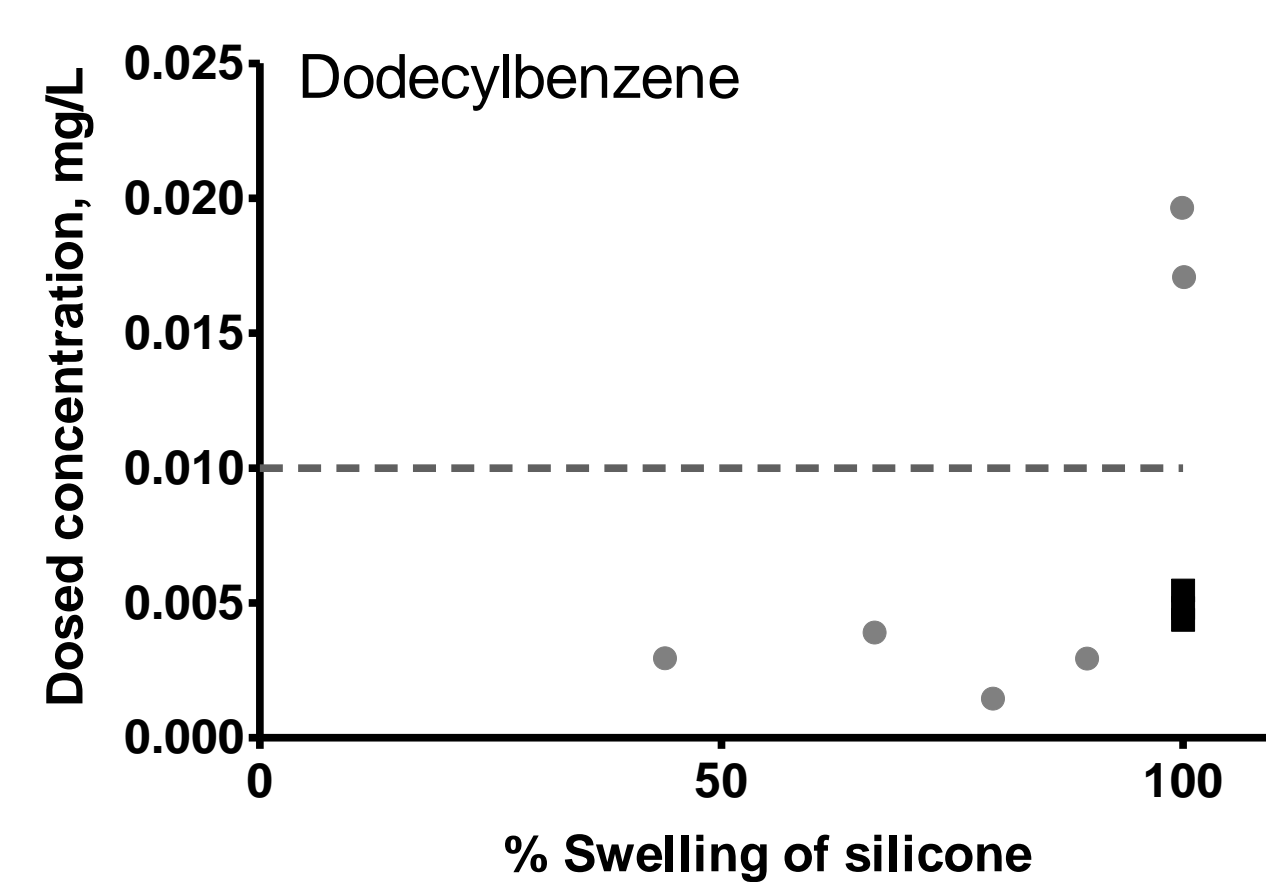


Figure 3: Direct passive dosing of dodecylbenzene from silicone rods loaded at varying swelling percentages

Conclusion

- Saturation of 3 mm silicone rod by swelling can be obtained within one day
- Direct passive dosing at 90% swelling agreed with headspace equilibrated solubility measurements
- Direct passive dosing at 100 % swelling produced markedly higher concentrations than headspace equilibration and direct passive dosing at 90 % swelling – third phase challenges
- Headspace dosing is a promising method for solubility determinations for volatile liquid chemicals
- Direct passive dosing for solubility measurements of hydrophobic chemicals requires further work

References: ¹Stibany, F., Schmidt, S.N., Schäffer, A. and Mayer, P. 2017. Aquatic toxicity testing of liquid hydrophobic organic chemicals – passive dosing exactly at the saturation limit. Chemosphere 167: 551-558.

²Trac, L.N., Schmidt, S.N and Mayer, P. Submitted. Headspace passive dosing of volatile hydrophobic chemicals – aquatic toxicity testing exactly at the saturation level.

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